TAMK University of Applied Sciences
Degree Programme of Environmental Engineering
Li Rong

Final Thesis

Management of Landfill Leachate

Supervisor Senior Lecturer Eeva-Liisa Viskari
Commissioned by TAMK University of Applied Sciences

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ABSTRACT

The aim of this work is to define the characteristic of landfill leachate and summarize the present knowledge in management of landfill leachate. Selected parameters were analyzed and compare to the result with landfill leachate composition, domestic wastewater characteristics and other research data. This final thesis is belonging to the landfill leachate project between Kunming Institute of Environmental Science in China and TAMK University of Applied Sciences in Finland. The aim of project is through the laboratory work and literature survey to discover and test innovative technology of landfill leachate treatment, and how to design the constructed wetlands to improve the treatment efficiency. In this final thesis the literature survey and some of laboratory analyses were done from leachate as preparative activity to help continue of the work in August 2009 in Finland.

Key words Landfill, leachate, leachate treatment, CWs, TSS, landfill design

Foreword

This final thesis was made for TAMK University of Applied Sciences and the Kunming Institute of Environmental Science Research during the spring of 2009. The thesis is belonging to the project names: Landfill of leachate treatment using different technologies. For the planning, the project will start on April of 2009. I written some of basic information for the management of landfill leachate and also prepared data from the experiment analysis to help the continue work.

I realized that the characteristics of landfill leachate are complex, but the leachate through the biological, chemical and physical processes will be treating a lot. I learned how to analyze the total suspended solid by design experiment and how to using the HACH Spectrophotometer to measure different chemical composition in leachate from the laboratory work.

I would like to thank my supervisor, Eeva-Liisa Viskari for her valuable guidance and help throughout my final thesis. Specially, I want to thanks for my husband, Shang Nan helps me to lend the related books about my thesis topic from his university library and also gave me lots of supports and encouragement.

And also, I would like to thank my roommate, Li Yanan and my parents for kindly give me a peace environment to finish my thesis.

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Li Rong

Table of contents

List of symbols

NH_3-N	mg/L	ammonia nitrogen
NH_4-N	mg/L	ammonium nitrogen
NO_3-N	mg/L	nitrate nitrogen
P	mg/L	phosphorous
N	mg/L	nitrogen
SS	mg/L	suspended solids
TSS	mg/L	total suspended solids
TDS	mg/L	total dissolved solids
COD	mg/L	chemical oxygen demand
TOC	mg/L	total organic carbon
BOD	mg/L	Biochemical oxygen Demand
Cr^{6+}	mg/L	Chromium
Fe	mg/L	Iron
PO_4^{-3}	mg/L	Phosphorus
SO_4^{2-}	mg/L	Sulfate
TWTP		Tarastenjärvi waste treatment plant
MWTPs		municipal wastewater treatment plants
CWs		constructed wetlands
SFCW		surface flow constructed wetlands
SSFCW		subsurface flow constructed wetlands

1. Introduction

The population growths followed by the urban development have increased fast, so the domestic solid wastes are produced and needs to be managed more frequently. The land filling has been to the main method of the waste management. The current landfill technology is primarily determined by the need to prevent and control leachate problem. (10) The management of landfill leachate has become to one of main focus for the environment management of landfill. The leachate normally generated by the rainfall and surface water flow into the landfill, through a period time, they change to the high concentrated wastewater on the bottom of the landfill. Actually, the leachate is a potential threat for the quality of groundwater. The landfill leachates contain complex compositions, such as High concentration of ammonia nitrogen and salt, the suspended solids, N, P and heavy metals, which are belong to the water quality characteristic of leachate also. Various factors could bring the difficult problems for management of landfill leachate. (25)

The method of landfill design consists of several parts related to the control of landfill leachate. However, the special landfill design for leachate control could be divided into three important keys: Pretreatment of landfill solids before the filling into the landfill. Cover system include the daily cover, intermediate cover and final cover. Bottom liners systems include the clay liner, plastic liner, composite liner and leachate collection system. Mass of the leachate treatment methods should through the biological process, physical process or chemical process. In order to saving the management cost, the landfill design could connect with the treatment methods for leachate, such as the nature treatment system – constructed wetland, which through the biological and chemical process to reduce the concentration of leachate. (8)

The aim of this work was to survey the present methods of landfill leachate management and find out basic information about the quality and characteristics of landfill leachate. This was done by literature survey about landfill design, leachate management and quality. It also included basic laboratory analyses about landfill leachate collected from a closed landfill site of Tarastenjärvi waste treatment plant (TWTP) in Tampere region in Finland. The target of the testing was through the basic laboratory experiment to analyze and realize the characteristic of leachates. In the laboratory analyses total suspended solids (TSS), pH and conductivity of leachate were analysed. Also the chemical composition of leachate sample using by HACH such as sulfate, phosphate, nitrate, iron and chromium were determined.

2. Landfill leachate

The general forms of waste treatment include landfill, incineration, refuse composting and pyrogenation. The landfill is an important and basic part for waste treatment in a majority of cities at present.

The problem with landfills is the landfill leachate pollution. Furthermore, the landfill leachate problem is a long term issue, since the landfill leachate is formed long time after closing the site. From the start till the end there should be effective control and management for the production of leachate.

2.1 Definition of leachate

Leachate means any liquid percolation through the deposited waste and emitted from or contained within a landfill. (1) The leachate consists of many different organic and inorganic compounds that may be either dissolved or suspended. (2) They will bring potential pollution issues for groundwater and surface waters in nature. The landfill leachate is a secondary contamination related to landfills. At present, leachates from most of landfills were treated by municipal wastewater in municipal wastewater treatment plants (MWTPs).

2.2 The generation of landfill leachate

The landfill leachate could be produced by two main causes. External water enters the waste and within the waste generated leachate.

2.2.1 External water

A. Most of leachate is generated by direct water is rainwater and snowmelt in to the waste. These liquid should spend many years infiltrate through the landfill, during this time, they will contact with various substances such as paints, plastic, oil etc. inside the landfill. The water leaches and dissolves various constituents until it contains a load of heavy metals, chlorinated organic compounds and other substances. (3) Finally, they become to the polluted liquid names leachate that can harm nearby surface-water and groundwater. The leachate water quality became serious after mass of rainwater washed landfill. Intension, quantity, frequency and duration of rainfall relate to quantity of leachate production. Otherwise, the humid climate has a strong influence for the generation of leachate. (2)

B. The surface-water and groundwater into the waste by inflow or infiltration. The surface-water depends on type of site, if the landfill building under a sloping field, which has surface-water, its will drop down into the landfill from the direction of topography. Otherwise, the groundwater is possible to infiltrate into the waste if the bottom of landfill under the water table. The quantity of leachate is based on interface situation (tangent time, tangent position and flowing direction) between groundwater and waste. (27)

2.2.2 Within the waste generated leachate

A. Quality of wastes. The wet waste contains excess moisture which consists of own moisture and the adsorbed moisture (from atmosphere or rainwater). The biological, physical and chemical processes take place there by the wet waste through compaction and organic decomposition in landfill. If this waste has a moisture holding capacity of 15% by weight (or 0.25m3/metric ton [60 gal per ton]), a total of 68 m3/day (18,000 gal/day) of moisture can be absorbed. (5) The waste moisture was produced by the waste during waste placement; such as solid waste without treatment into the landfill will produce leachate that is a main source.

B. some of organic components inside the waste, which is through the anaerobic decay becomes heavy polluted liquid within the landfill. The total liquid of production relate to component of waste, ph, temperature and type of bacteria.

The generation of leachate also depends on other factors:

- Quality of wastes and its crumbling;
- Techniques of land-filling and degree of waste compaction;
- Age of landfill;
- Precipitation, humidity (6)

2.3 The factor of influence for water quality of leachate

The composition of landfill leachate is complexity, high concentration of pollutants and variation. The water quality and water quantity of leachate relate to main factors: composition of solid waste, local climate, age of landfill and method of land-filling, Due to many of factors connect with the different site of landfills and the different time of landfills, and factors brought the numerous variation of leachate water quality and quantity. (10)

2.3.1 Composition of waste

The composition of waste for landfill leachate water quality has large influence. Within the landfill leachate contains COD_{Cr}、BOD_5 are producing from the organic matter of domestic biological waste are mostly. The content of domestic biological waste, which is high or low within waste could direct influence the concentration of COD_{Cr}、BOD_5. Otherwise, the remains of dust and soil are provide with the function of adsorption and filtration for organic matter by chemical processes within leachate, therefore, the contents of dust and soil within waste could influence the concentration of leachate also. (25)

2.3.2 The effect of landfill age on leachate

The waste treatment in landfills is a process of circulation: land-filling, coverage and press. The different sites of landfills stay with the different stages. Leachate can be divided into different types according to the age of landfill: the leachate of young landfill (above 3-5 years), the leachate of medium and old landfill (over 5 years). Table 1 shows a result about the typical concentration of leachate in relation to the age of landfill. Almost all the concentrations reduced with increasing age of the landfill; except NH_3-N is more abundant in the leachates of young landfills where active decomposition of organic material in the waste is taking place. (12)

Table 2.1 Variation with age in the typical concentrations of common factors of landfill leachates (12)

Factors/property	Age of landfill		
	Young	Medium	Old
pH	5.7-8.0	6.4-8.0	6.6-8.3
BOD(g/l)	7.5-17.0	0.37-1.1	0.07-0.26
COD(g/l)	10.0-48.0	1.2-22.0	0.67-1.9
N(NH3)(g/l)	0.04-1.0	0.03-3.0	0.01-0.9
Cd(mg/l)	0.02-0.01	0.04-0.08	0.01-0.14
Cu(mg/l)	0.08-0.30	0.02-0.11	0.03-0.12
Pb(mg/l)	0.05-0.92	0.04-0.08	0.03-0.12
Zn(mg/l)	0.53-34.2	0.18-0.22	0.19-0.37

2.3.3 Method of land-filling for water quality of leachate

The different land-filling technology affects the quality and quantity of leachate. Flood-control system at the landfill that is useful to assist surface-water discharge. In addition using the yellow-clay lay on the bottom of landfill to control the flowing surface-water and groundwater into the landfill is preferable, so the concentration of organic matter within the leachate is higher than normal wastewater. If the landfill bottom using the normal clay to prevent leachate infiltrate into the groundwater or the surface-water control is not successful, these situations is probably to reduce the concentration of leachate, but water quantity of leachate will increase quick and more. (26)

2.4 Composition of landfill leachate

Leachate consists of water, organic, inorganic and bacterial compounds together with solid. Definition of all the compositions in leachate is difficult, complex, expensive and time-consuming. The compositions of leachate can be divided into four parts of pollutants. Organic matter such as: COD (chemical oxygen demand) and TOC (total organic carbon); specific organic compounds, inorganic compounds and heavy metals. (10) However, the organic content of leachates is often measured through analyzing sum of parameters such as COD, BOD (biochemical oxygen demand) and TOC and dissolved organic carbon. Typical ranges of the concentration of selected parameters in leachate are shown in following Table 2. (11)

Table 2.2 Chemical composition of landfill leachate- concentration ranges (mg/L). (11)

Parameter	**Range (mg/l)**
PH (no units)	3.7- 9
Hardness	400- 2,000
Total Dissolved Solids (TDS)	0- 42,300
Chemical Oxygen Demand (COD)	150- 6,000
Biochemical Oxygen Demand (BOD)	0- 4,000
Total Kjeldahl Nitrogen (TKN)	1- 100
Ammonia	5- 100
Nitrate	<1- 0.5
Nitrite	<1
Sulphate (SO4)	<1- 300
Phosphate (PO4)	1- 10
Aluminum	<0.01- 2
Arsenic	0.01- 0.04
Barium	0.1- 2
Beryllium	<0.0005
Boron	0.5- 10
Bromide	<1- 15
Cadmium	<0.01
Calcium	100- 1,000
Chloride	20- 2,500
Cobalt	0.1- 0.08
Copper	<0.008- 10
Chromium	<0.01- 0.5
Fluoride	5- 50
Iron	0.2- 5,500
Lead	0- 5
Magnesium	16.5- 15,600

Manganese	0.06- 1,400
Nickel	0.4- 3
Potassium	3- 3,800
Selenium	0.004- 0.004
Sodium	0- 7,700
Zinc	0- 1,350

2.5 Characteristic of landfill leachate

The leachate is highly polluted wastewater. The solution has many different physical, chemical and biological characteristics. Currently, the change range of pH is 4~9, the range of COD is 2000~62000mg/l and BOD_5 is 60~45000mg/l. Especially in the initial process of landfills, the COD_{Cr} might be up to 90000mg/l in the leachate. (13) In the following I will introduce some of normal characteristics of leachate.

2.5.1 Color and smell

The color of leachate is orange-brown or dark-brown; the chroma is around 2000, sometimes can up to 4000. Associated with the leachate is a malodorous smell, due mainly to the presence of organic acids, (14) which come from the high concentration of organic matter was decomposed. Such as dark color and malodor will disappear slowly or change to light, which is relate to the increasing age of landfills, otherwise, these change should connect to the nature of precipitation and the quantity or quality of industry waste.

2.5.2 pH

The pH of initial landfills is 6~7, which is present weak acidity. Along with time was passed that the pH can up to 7~8, which is present weak alkaline. The pH will tent to alkaline according to the increasing age of landfills, similarly, these change also connect to the nature of precipitation and the quantity or quality of industry waste.

(28)

2.5.3 BOD

The activity of microorganism was increased by time was processed, such as the BOD was increased also in the leachate. The BOD will up to the maximum value when the normal Land-filling is processing from 6 months to 2.5 years. The BOD becomes very deliquescent, which is a main characteristic. Finally, the BOD index start to reduce until the landfill is steady should through 6~15 years. (28)

2.5.4 COD

Effluent COD values are 200~300mg/l, down from 300~500mg/l. (15) The CODcr is lower in the initial stages of landfills (normal could reach to over ten thousand). The reduction of COD is slow and the decrease of BOD is fast by time was processed. The reduction of BOD_5 or CODcr leads to the biochemical treatability is reducing. (15)

2.5.5 TOC

The concentration of TOC is 265~2800mg/l normally. The BOD / TOC could reflect the oxidation of organic carbon in leachate. The value of BOD /TOC is high in the initial stages of landfills. The landfill is steady along with the process of time, so the oxidation of organic carbon in leachate brings the value of BOD /TOC is reduced. (28)

2.5.6 TDS (total dissolved solids)

The change of TDS relate to the age of landfills in leachate. In the initial stages of landfills contain the concentration of total soluble salt (TSS) is up to 10000mg/l, and also contain the sodium, calcium, chloride, sulphate and iron. Afterwards, the concentration of inorganic matter will reduce when the age of landfill through 6~24 months up to the maximum value.

2.5.7 Suspended solids

The suspended solid means solid matter in the leachate, and they consist of organic matter, inorganic matter, clay and microorganism etc. Effluent values are typically 3~10 mg/l, down from 9~80. (15) Leachate from landfills normally contains only small amounts of suspended solids, however, if landfills are occur an unwonted situation, and then the suspended solid will change to more. Fortunately, the treatment method of suspended solid is easier than other components in leachate treatment.

2.5.8 Salts

The high concentration of salt in the leachate mostly is chloride (100~4000mg/l) and phosphate (9~1600mg/l), which are more serious when the rainfall is less in that zone. The leachate should through the process of desalination treatment before the leachate need to reuse. (15)

2.5.9 N, P

The N and P are main components within the inorganic pollutant from the leachate. The concentration of N and P is high when the landfill in the processing. However, when is landfill is closed, the P is reduced slowly, but the N will rise step by step, because the decomposition of waste is a slow process under the anaerobic conditions, the waste will continue to decompose when the landfill is closed. The leachates contain the high concentration of N and P, which is due to their increase, these situations will continue some of years. Therefore, the leachate including the high concentration of N and P after landfill closed is more difficult treatment than the laechate in the processing of landfill. (15)

The main component of ammonia nitrogen is contains ammonia, which is normally contains around 0.4g/l and sometimes up to the 1.7g/l, the content of organic nitrogen is about 1/10 of total nitrogen. The concentration of ammonia nitrogen is increased according to the increase of filling time. The nitrogen is around 40%~50% of total ammonia nitrogen in the leachate, and the nitrogen mostly exists by the form of ammonia nitrogen. The high concentration of ammonia nitrogen brings unbalance of scale for the nutrition elements of microorganism. (28)

2.5.10 Heavy metals

The high content of heavy metals because of the domestic waste was filled together with the industrial waste or sludge in landfill, except the individual land-filling. The amount of heavy metals is related to the industrial level of local urban and how much industrial waste will be land-filling. The domestic waste only contains heavy metal is low. If the any waste adopt the mode of mix-filling in landfill, and then the industrial waste is account for most part, which is main source for the content of heavy metals. The normal heavy metals ionic consist of Cu, Zn, Pb, Cd, Hg etc. (28)

2.5.11 Variation in leachate quality

The time of land-filling is a main factor for water quality of leachate. The BOD/COD is 0.4~0.75 within leachate. The waste is stable day by day according to the time of land-filling is increased, at the same time, the concentration of organic matter will reduce within landfill leachate, the value of BOD/COD is possible under 0.1. This result is indicates the efficiency by using the biological method treat landfill leachate according to the increase of land-filling time will change to low, and the latter process of treatment change to more difficult. The water quality of leachate is very variable, so the technology of treatment system should be developed strongly.

3. Design of landfill for leachate control

The level of landfill design has enhanced is based on technology, economy and society develop in recent year. A major landfill design and operation should consider a number of conditions in beginning of the project, actually, most of conditions related to the leachate control and treatment. The designs are different between industrial and municipal landfills.

3.1 General landfill design

The general landfill design includes the following requirements: site preparation, buildings, monitoring well, size, liners, leachate collection system, final protective cover, and gas collection system. The landfill divide into two kinds of form in city: waste landfill and sanitary landfill. The sanitary landfill could beautify urban environment, but they don’t have material difference. Following table 3.1 will introduce an example, what kind of factor could be contented requirement when they need to build a sanitary landfill. (4)

Table 3.1 Design of sanitary landfill (4)

Design Factor	Description
Solid waste	Realize current and future solid waste generation rate and chemical composition.
Site	Complete the survey of site - Prepare the base maps of current conditions on and near site: ground contours, surface waters, wetlands, roads, structures and other land use. - Develop soil textural information: soil type, depth, texture, structure, size, density, permeability, moisture content, profile, pH - Develop hydrological data: groundwater depth, quality, seasonal change, direction of flow, rate of flow, current and future uses - Identify and characterize soil cover: texture, permeability and quantity - Identify regulation: state, local design standards, local permit requirements, building codes
Filling area	Select landfill method based on site, soil, bedrocks, groundwater - Design elements: width, depth, length. Liner thickness, base construction and leachate collection, interim and final covers - Operational features: type of soil cover, method of cover application, need for imported cover, equipment requirement, personnel requirements
Waste filling and compaction	Develop initial site plan of fill area and landfill contour plan - Compute solid waste storage volume, soil requirement volume, and site life - Develop site plan showing: normal fill areas, special working areas, control systems for leachate, gas, surface water, access road, structures, lighting, monitoring wells, landscaping - Prepare ultimate land use plan - Prepare cost assessment and design report - Prepare environmental impact assessment - Submit application and obtain required permit - Prepare operator's manual - Prepare plans for closure and post closure care

3.2 Key of landfill design

According to the description of design factors to analyses what kind of conditions is a key for prevent and control the production of leachate?

3.2.1 Pretreatment of Solid waste

The quantity and quality of solid waste relate to production quantity of leachate. The generation of leachate part has already explained the reason. The economic statistic of solid waste output was set up in a department to record and statistic the generation rate current. If mass of solid wastes will produce in the future, they should complete planning carefully, so the background of data is a first factor for beginning of the landfill design. The chemical composition connects with the pretreatment of solid waste, which is helpful for the leachate control. A good pretreatment will reduce the chemical composition before the solid waste filling into the landfill. (4)

3.2.2 Cover system

The landfill cover system is a key part for landfill design. Its main aim is to isolate within the landfill from the infiltration of water and also to prevent the generation of leachate. The cover should have lower-permeability than the bottom liner to prevent surface water flow into the landfill. The cover system could be designed to help the growth of plants in order to protect the landfill in the future. Three types of covers are used in the landfill.

Daily Cover is a layer of soil, which is cover on the top of landfill after the everyday working end. The sandy soil is normal, but other cover materials also could be used, such as wood, clay, sand and chemical foams. Daily cover thickness can be 0.6 meters, so the truck can drive over the landfill easier. Daily cover should remain also during precipitation that falls on the landfill. The function of daily cover prevents the animals eating or taking the waste to other place and spread diseases and also reduces the chance of fire and bad smell.

Intermediate cover will not be covered for long time. If the landfill working should stop a period of time, the landfill must be covered using more soil than in daily cover in order to reduce the amount of rainfall infiltration into the waste. The intermediate cover is also could lead to the water run off to the surrounding area of landfill. The thickness of the intermediate cover is about 1.2 meters. Some of landfills will plant the vegetation on the top intermediate cover as protection when the filling work should stops long-term, and also could remove the vegetation if the landfill should work again.

Final cover for landfill can be form 0.6 to 2 meters thick. When the landfill reaches the maximum capacity, which is must be covered with low-permeability or man-made chemical material. Connect with the drainage layer to take the moisture away from the landfill. The final cover is promoting the runoff of rainwater and prevents infiltration step by step, and also preventing the leachate production. The vegetative layer is planted on the top of final cover, and this layer not only prevents erosion but also promotes runoff and evaporation. The soil and plant types will influence final effect.

3.2.3 Bottom liners system

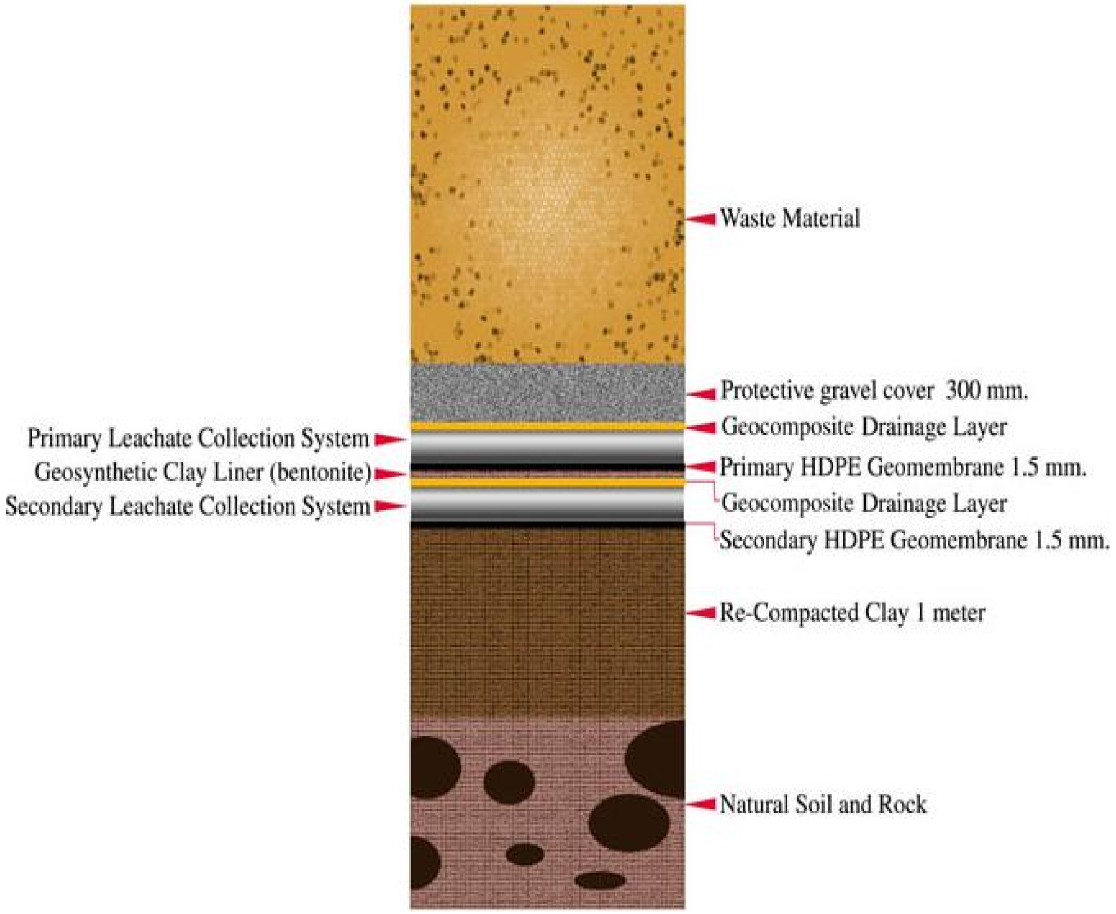

Figure 3.1 Detail of a bottom-liner system (16)

The bottom liner system is a most important part of landfill design. Figure 1 shows a detail of bottom liner system in the landfill. The liner usually has three types of: clay, plastic and composite.

The **clay liner may be problematic**. The natural clay tends to crack when it dries. However, the clay should be reworked and compacted to make it watertight which is a good liner for landfill, as shown in figure 3.1. Figure shows the geosynthetic clay liner always between the primary leachate collection system and secondary leachate collection system. The **plastic liner** is called geomembrane, such as high-density polyethylene (HDPE). The plastic liner can use alone or together with the clay liner to prevent the inflowing water in the short time, and they could be damaged easily by heavy equipment. The figure 1 shows the primary and secondary HDPE was used always under the leachate collection system. The **composite liner** is a single liner made of two parts: a plastic liner and compacted soil, such as clay soil normally. The figure 1 shows the geocomposite drainage layer above the leachate collection system to prevent and control the liquid infiltration. (16)

The most important part of bottom liner system is **leachate collection system**, which is located between the plastic liner and composite liner and that is impermeable layer. The bottom of the landfill is sloped. The leachate collection system is using the pipe place along the bottom to collect the wastewater and leachate within the landfill. These pipes lead the leachate and wastewater sends to the local wastewater treatment plant. Possibly, the leachate after treatment could back into the landfill to enhance decomposition. (16)

4. Treatment methods of the landfill leachate

The methods of leachate treatment can be divided into biological, physical and chemical methods. Usually, two kinds of methods should be combined to deal with leachate. Otherwise, the natural treatment systems connect with the landfill design is not only saving the cost, but also enhances the efficiency of treatment. For example constructed wetland is very useful. This chapter will introduce some different methods to in leachate treatment technology.

4.1 Biological, physical or chemical leachate treatment

The biological treatment divides into aerobic process and anaerobic process. The advantage of anaerobic process is that these allow heavy metals to be removed from the leachate by precipitation as carbonates. (17) The anaerobic treatment system includes the complex organic compounds that are transferred to CH_4 and CO_2, and also produces excess sludge that does not need so much management. The energy consumption of anaerobic process is lower than aerobic process. However, the high NH_4^+-N concentration within the leachate is often not completely reduced through the anaerobic process. (17)

The aerobic process is very useful if the leachate contains fatty acids of biodegradation. Microorganisms under in aerobic conditions keep up the biological activity of the process. Especially, when the leachate contains the high concentration of organic matters, the oxygen is necessary. The organic load of leachate according to the time was changed, so the system could control the supply of oxygen quantity. The aerobic processes could remove NH_4^+ efficiently and that processes can be carried out over a wide range of temperatures. Also, many substances are degraded at a higher rate in the aerobic process than in the anaerobic process.

The leachate still contains many of pollutants after biodegradation, such as heavy metals and some of persistent organic compounds. These compounds must go through the physical and chemical processes. The efficiency of the biological treatment method is connected with the stabilization of landfill. The aerobic process or anaerobic process should be processed together with physical pretreatment, which could improve the efficiency of the treatment.

The aim of physical and chemical treatment is ton remove heavy metal ions and NH_3-N (ammoniac nitrogen), although the physical and chemical treatment couldn't completely replace the biological treatment. Methods like adsorption, oxidation and ammonia stripping etc. belong to the physical and chemical treatment and, they could be a pretreatment to help the biological treatment process. That is also an effective method to help the leachate treatment to meet the standard and then is disposed. In order to achieve the best result the leachate treatment should be a combination of different technologies.

If the leachate contains high concentration of NH_4^+-N and COD, the leachate needs to be treaded by combined biological, physical or chemical treatment. The concentration of ammonium ion through the nitrification process could be reduced. In methanogenic leachates, the main part of the organic matter is refractory, so that a physical or chemical treatment method is needed to achieve acceptable level of COD removal. (18)

4.2 Natural treatment system - constructed wetlands (CW)

Actually, the leachate treatment technology of constructed wetland is normally applied in both developed and developing country. The constructed wetlands are an innovative treatment technology for leachate. The wetland consists of water, soil and wetland plants. They are dividing into natural wetlands and constructed wetland. The advantages of constructed wetlands are low costs, simple operation technology and maintenance in landfill leachate treatment, and they also could reduce human health or environment hazard risk. The idea of CW system bring some of new environment conceptions to human when they develop treatment technology, such as saving sources, respect nature environment.

The constructed wetlands could provide a nature treatment system to reduced the pollutant concentrations and total leachate volume through the biological and chemical processes, at the same time, they could remove or reduce some of major components from the landfill leachate including BOD, NH_4^+, P, K, Ca^{2+} and selected metals. (7, 8)

Usually, the basic principle for the design of constructed wetland is to plant some of wetland plants, such as reed and willow are useful and they belong to the typical wetland plants. The water quality of wastewater can be cleaned by filtration through sandstone or soil, and within the root zone of plants has mass of microorganisms using their various functions to break or absorb components. The wastewater treatment system of CW in consists of wetland plants, control wastewater pipeline and valve, the prevent infiltration system to control the wastewater harm to groundwater.

At present, the treatment technology of CW is mainly dividing to two types: the surface flow constructed wetlands (SFCW) and subsurface flow constructed wetlands (SSFCW). The type of SFCW is let the sewage directly flow into the wetland, and then discharge after them remain within the wetland some days. This is a low cost treatment method, but the problem is that sewage is directly exposed with the atmosphere. This situation will lead to the pollutants directly diffused through the air and thus they could produce the secondary pollution. The sewage is easily freeze will influence the efficiency of treatment in some of cold areas, such as Scandinavian countries. The type of SSFCW is using the pipeline leading the sewage from the landfill to the wetland and then the processes take place on the bottom of water bed, which is planted wetland plants. The method of SSFCW treat with sewage is highly efficient, without malodors. This method could be used in the cold areas. The wetland plants absorb and accumulate the pollutants in the leachate. The quality and density of wetland plants is related to the treatment efficiency. The reed is a good wetland plants for SFCW and SSFCW.

The wetlands system is based on biological and chemical reaction to remove the contaminants from leachate. These reactions take place within or around the plant root zone, which is also named beds (e.g. reed beds system). These plant functions are beneficial for the efficient treatment of landfill leachate because they provide the oxygen for breakdown of organic compounds and NH_4^+ and might offset plugging by large metal loads in leachate. (8)

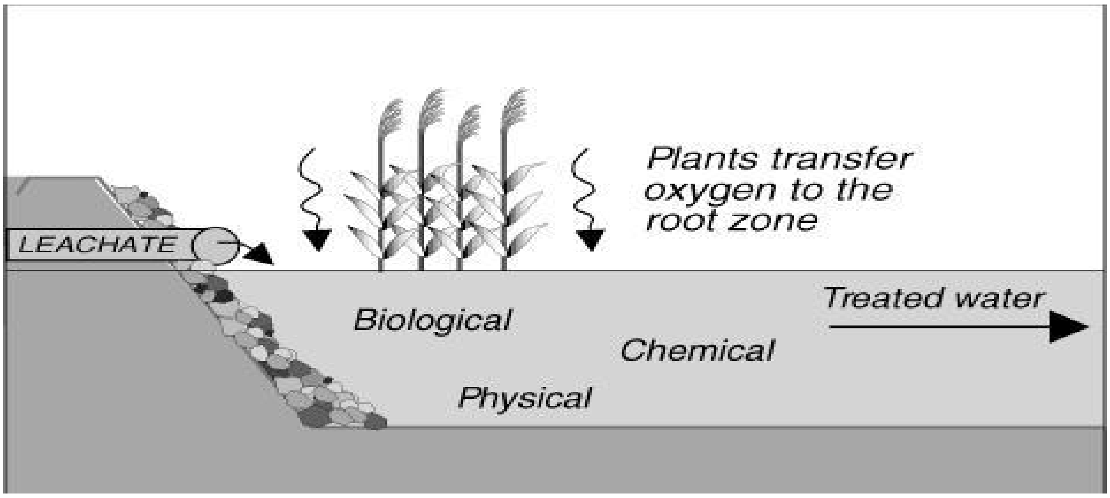

Figure 4.1 Contaminant removal processes in a constructed wetland. (9)

The figure 4.1 presents the contaminant removal processes of landfill leachate in SFCW. The leachate through the pipeline flows into the constructed wetland, and the wetland plants could transfer oxygen to the root zone.

The removal efficiency of CWs system treating leachate pollutants is good for total suspended solids (TSS), total dissolved solids (TDS), chemical oxygen demand (COD), total organic carbon (TOC) and heavy metals etc. The influent landfill leachate through the CWs system, the pH is change to balance. The table 4.1 presents the removal efficiency of CW in one experiment.

Table 4.1 Removal efficiency of free water surface constructed wetlands treating landfill leachate (20.)

Constituent	Influent	Effluent	Percent removal (%)
pH	6.32	6.86	-
TSS(mg/L)	1008	30	97
TDS(mg/L)	1078	396	63
COD(mg/L)	456	45	90
TOC(mg/L)	129	17	87
Copper(mg/L)	0.05	0.024	52
Lead(mg/L)	0.078	0.004	94

5. Laboratory analyses

The laboratory experiments through the measurement of landfill leachate provided the basic information about leachate quality. The processes of experiments were done according to the suggestion of supervisor. The analyses included total suspended solids (TSS), the pH and conductivity. Using the HACH Spectrophotometer sulphate, phosphate, nitrate, iron and chromium were measured.

5.1 Leachate sampling

The Leachates were sampled from Tarastenjärvi waste treatment plant (TWTP) in the Tampere region (Finland). The plant belongs to the Pirkanmaan Jätehuolto Oy, which is owned by 23 municipalities in Tampere area and it is serving about 376 000 inhabitants. They accepted commercial and household waste. The old landfill sites was in operation from 1977 until 2007, and it were they were closed three years ago. The figure 5.1 shows the landfill leachate evaporation pond. The bottom of leachate evaporation pond is rock to prevent the leachate infiltration to pollute the groundwater. The natural evaporation is used to reduce the quantity of leachate. The leachate from the old landfill, which is evaporated around 40% from the original quantity within some years. Around the pond there is a lot of biowaste being decomposed with the residual wood, and also some of plants grew in the surrounding area.

The sampling equipment included a canister (20L), gloves and sampling rod (5 meters when it was extended) from the TAMK laboratory. The surface area of leachate evaporation pond is over 200 m^2, but the depth is between 1 to 10 meters. The sample was taken from the leachate pond using by the sampling rod. The sample size was about 5 liters. The temperature during sampling was 10 degrees centigrade. The less rainfall quantity in the spring of Tampere could enhance the efficiency of leachate evaporation process. Below the figure 5.1 shows the location for the sampling.

Figure 5.1 Sampling locations in Tarastenjärvi Landfill

5.2 Sample pretreatment and preservation

The sample was cleaned from unwanted substances such as leaves, sticks, animal feather, which were excluded from the sample. If the unwanted substance was included within the sample, the determination of final result will be influenced. The sample through the pretreatment and then put them into the refrigeration to preserve by several days, the process of analysis should begin as soon as possible.

5.3 Determination of total suspended solids

Total suspended solids (TSS) indicate the turbidity of the water. Suspended solids cause the water to be milky or muddy looking due to the light scattering from very small particles in the water. Sometimes it is mixed with color, but colored waters can also be clear. Polluted waters are commonly turbid and improvement is usually marked by greater clarity.

5.3.1 Materials for TSS experiment

- Three Whatman's glass microfiber filters grade GF/A, circles 110mm
- Glass beaker 1000ml
- Three glass dishes
- Tweezers
- vacuum flask 1000ml and vacuum tubing
- graduate cylinder 250ml
- glass filter holder (funnel) with rubber adapter
- Drying oven for operation at 103-105°C
- Glass Desiccators
- Analytical balance, capable of weighing to 0.01g
- Raw leachate sample and distilled water

5.3.2 Procedure for TSS experiment

Glass fiber filter GF/A was weighed. The sample was a vacuum filtrated through the filter and dried in 105°C for 1-2 hours and weighed again after cooling in a desiccator.

Figure 5.2 The installation of vacuum filtration

5.3.3 Result and calculation

The original color of the leachate is dark brown and after the process of filtration, the color of leachate sample is clear brown. Base on the data shows on the bench sheet to calculation the result for how much total suspended solids in the leachate sample. The unit is mg/l (Table 5.3.1).

Table 5.3.1 The result of filter samples

Filter sample number		sample 1	sample 2	sample 3
Volume filtered (ml)	C=	300	150	140
Filtered weight (mg)	A=	576.1	546.5	539.8
Initial weight (mg)	B=	510.1	512.5	508.2
Net weight (mg)	A-B=	66	34	31.6
TSS content (mg/l)		220	226.7	225.7
Average TSS content (mg/l)		224.1		

Caculation method:

$$Sample1 = \frac{(A_1 - B_1)*1000}{C_1} = \frac{(576.1 - 510.1)mg*1000}{300*10^{-3}l} = 220mg/l$$

$$Sample2 = \frac{(A_2 - B_2)*1000}{C_2} = \frac{(546.5 - 512.5)mg*1000}{150*10^{-3}l} = 226.7mg/l$$

$$Sample3 = \frac{(A_3 - B_3)*1000}{C_3} = \frac{(539.8 - 508.2)mg*1000}{140*10^{-3}l} = 225.7mg/l$$

$$Average = \frac{(220 + 226.7 + 225.7)mg/l}{3} = 224.1mg/l$$

5.4 HACH Spectrophotometer measurement for chemical composition

Heavy metals - Iron (Ferro) and chromium and nutrient salts like phosphorus, nitrate and sulfate were also measured using HACH spectrophotometer.

The leachate sample was filtrated into the 1000ml vacuum flask through the TSS experiment. The filtrate was used for analysis. The samples were diluted when needed.

5.4.1 Materials for HACH measurement

- HACH Spectrophotometer DR2010 (figure)
- Two groups of sample cells (10ml and 25ml)
- Reagents (five types)
- 25ml pipette with the calibration mark
- 250ml graduated-volumetric flask with the calibration mark
- Two 500ml beakers

- Suction bulb for safe pipette
- Three 5ml plastic pipettes
- Glass stirring rod
- Filtrated leachate sample and distilled water

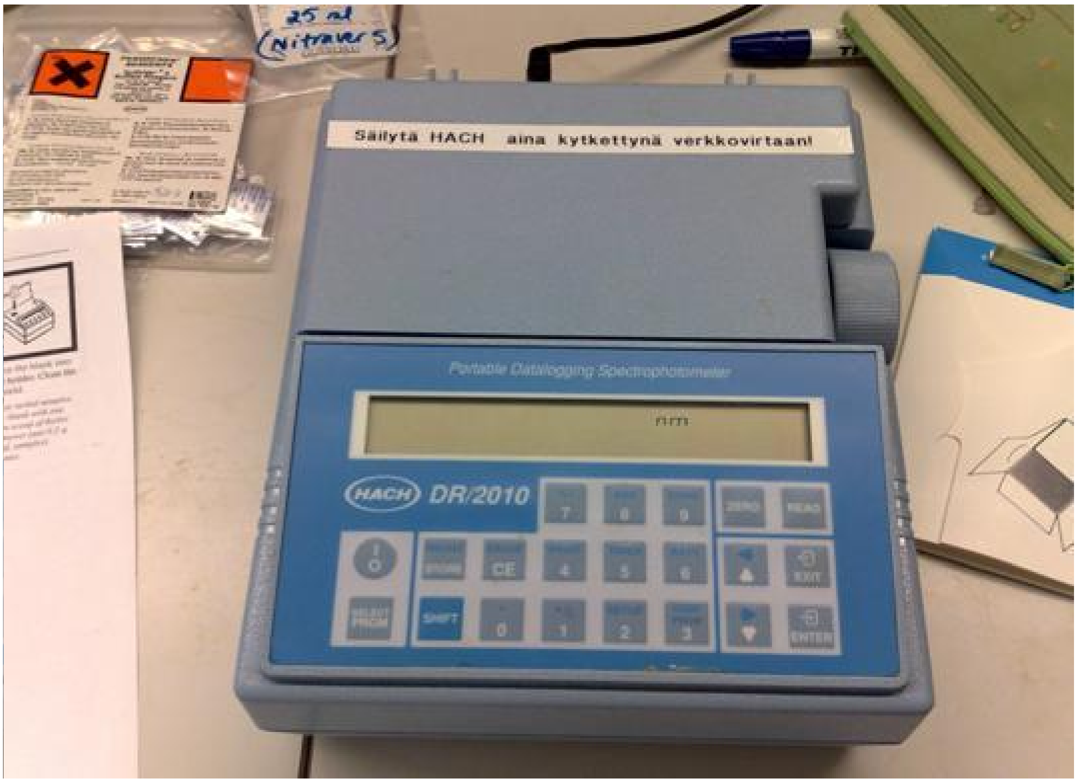

Figure 5.4.1 The HACH Spectrophotometer DR2010.

5.4.2 Result of measurement

(a.) Iron, total (0 to 3.00mg/L Fe)

The size of sample cell is 10ml and each measurement needs to wait three minutes. 1:10 diluted leachate samples were tested two times. The color of sample change to light orange after the Ferro Ver Reagent Powder Pillow was added. The first result is 1.48mg/L Fe and the second result is 1.44mg/L Fe. The range of result is from 0 to 3.00mg/L Fe, so the result of two times is allowed. The average result is 1.46mg/L Fe, which means the content of total iron is 1.46mg in the 1L leachate sample.

(b.)Phosphorus, reactive (0 to 2.50mg/L PO_4^{-3})

The size of sample cell is 10ml and each measurement needs to wait two minutes. The samples were diluted 1:100. The color of sample change to light purple after the Phos Ver 3 Phosphate Powder Pillow was added. The power pillow is hardly dissolved in the sample. The first result is 0.68mg/L PO_4^{-3}PV and the second result is 0.54mg/L PO_4^{-3}PV. The range of result is from 0 to 2.50mg/L PO_4^{-3}PV so the result of two times is allowed. The average result is 0.61mg/L PO_4^{-3}PV, which means the PO_4^{-3} has 0.61mg in the 1L leachate sample.

(c.) Chromium, hexavalent (0 to 0.6mg/L Cr^{6+})

The size of sample cell is 10ml and each measurement needs to wait one minute. Samples were diluted 1:10 and the raw filtered leachate sample was tested four times. No color change in the sample after the Chroma Ver 3 Reagent Powder Pillow was added. The first result is 0 mg/L Cr^{6+} and the second result is 0mg/L Cr^{6+} from the 1:10 sample. The third result is -0.06mg/L and the fourth result is -0.03mg/L from the raw sample. The range of result is from 0 to 0.6mg/L Cr^{6+}, so the result of four times is un-allowed, which means the leachate sample without the Cr^{6+}.

(d.) Nitrate, HR (0 to 30.0mg/L NO_3^--N HR)

The size of sample cell is 25ml and each measurement needs to wait one minute. 1:10 diluted leachate samples were tested by two times. The sample appeared the black precipitate after the Nitra Ver 5 Nitrate Reagent Powder Pillow was added. The first result is 1.2 mg/L NO_3^--N and the second result is 1.0 mg/L NO_3^--N. The range of result is from 0 to 30.0mg/L NO_3^--N, so the result of two times is allowed. The average result is 1.1 mg/L NO_3^--N, which means the NO_3^--N has 1.1mg in the 1L leachate sample.

(e.) Sulfate (0 to 70mg/L SO_4^{2-})

The size of sample cell is 25ml and each measurement needs to wait five minutes. 1:10 diluted leachate samples were tested two times. No color change in the sample after the Sulfa Ver 4 Sulfate Reagent Powder Pillow was added. The first result is -2mg/L SO_4^{2-} and the second result is -1mg/L SO_4^{2-}-N. The range of result is from 0 to 70mg/L SO_4^{2-}, so the result of two times is un-allowed, which means the leachate sample without the SO_4^{2-}.

5.5 pH and conductivity of measurement and result

The pH measurement using by the equipment names standard pH meter, PHM210. The pH measurement can be performed by using the AUTOREAD function which locks the result on the display as soon as the electrode signal has stabilized. The value was stable about three minutes. The value of pH for the leachate samples is 7.17 in 22 degrees centigrade.

The Conductivity of measurement using by the equipment names conductivity meter, CDM210. The conductivity of measurement could use the AUTOREAD function also. As soon as the conductivity measurement has been accepted and corrected to the reference temperature. The result is automatically present after a visual stability indicator STAB is displayed. The value of conductivity for the leachate sample is 3.539mS/cm in 22 degrees centigrade.

6. Discussion of experiment result

According to the analysis experiment of selected parameters to make a table to concentrated present the whole results (Table 6.1). At first, the quality value of industry landfill leachate range in Finland and Canada will be present to compare with the quality value of leachate sample in this experiment. The second step was to compare with the domestic wastewater.

Table 6.1 Selected Parameters in landfill leachate by experiment. BDL= below detection limit.

Parameters	**Unit**	**Landfill Leachate**		
		Minimum	**Maximum**	**Mean**
Suspended solids	mg/L	220	226.7	224.1
Conductivity	mS/cm	3.538	3.540	3.539
pH	-	7.16	7.18	7.17
Chromium	mg/L	BDL	BDL	BDL
Iron	mg/L	1.44	1.48	1.46
Nitrate, HR	mg/L	1	1.2	1.1
Phosphorus	mg/L	0.54	0.68	0.61
Sulfate	mg/L	BDL	BDL	BDL

Table 6.2 The quality of industrial landfill leachate in Canada and Finland (22.)

Parameter	**Unit**	**Canada** 1)		**Finland** 2)
		Mean	**Range**	**Range**
pH	-	7.4	6.8-8.6	6.8-7.0
Conductivity	mS/cm	8.24	0.58-39.9	3.2-4.4
Nitrate	mg/L	10	<0.1-54	-
Sulfate	mg/L	152	<0.5-1460	-
Phosphorus	mg/L	3.5	0.6-7	0.72-2.5
Chromium	mg/L	0.008	<0.01-0.0066	0.004-0.08
Iron	mg/L	3.6	0.85-5.9	18.2-31
Suspended solids	mg/L	-	-	-

1) Three landfills, number of samples 6-17.

2) One landfill, number of samples 6-10 in 1990-1994.

All other results except the suspended solids without value presented in Table 6.1, were compared to the results in this experiment. The pH of leachate sample is 7.17 is almost within the range of 6.8-7.1 in Finland, but it lower than the mean value which is 7.4 in Canada (Tables 6.1 and 6.2). The pH from the landfill leachate is 7.1>7, the leachate is neutral. The pH range of domestic wastewater is 7-8, and the mean value of pH is 7 normal. So the pH of landfill leachate was in accordance with this information. The conductivity is 3.529mS/cm and is in accordance with the Finnish results, but lower than Canadian value 8.24mS/cm (Table 6.2).

The mean value of nitrate in measurement is 1.1mg/L, which is lower than the mean value of 10 in Canada. The nitrate value of Finland landfill is not available. The mean value of iron in measurement is 1.46mg/L, which is lower than the mean value is 3.6 mg/L in Canada. For comparison the concentration of nitrate is 0.0005mg/L in diluted domestic wastewater. The concentration of nitrate is higher in leachate than in domestic wastewater.

The range of iron is 18.2-31, which is the highest value measured in the Finnish study. Actually, the iron was measured from industrial landfill leachate and seems to be higher than in domestic landfill leachate in Finland. The mean value of phosphorus in domestic leachate sample is 0.61mg/L, which is lower than the mean value 3.5mg/L in Canada. However, it is lower than the range of 0.72-2.5 mg/L measured in Finland. The concentration of iron in diluted domestic wastewater is 0.6mg/L. It seems that iron is present in higher concentration in leachate than in domestic wastewater (Tables 6.2 and 6.3).

The mean values of chromium and sulfate were below detection limit. The typical sulfate concentration in untreated wastewater range from 20 to 50mg/L, in general, in crease about 15 to 30mg/L due to domestic use. Sulfate is an important in the growth of plants, and S is an essential nutrient. Thus the presence of SO_4^{2-} in reclaimed wastewater can be helpful, particularly for solid deficient in sulfur. (21.) Typical total phosphate concentration in untreated wastewater range from 2 to 20mg/L, include 1 to 5mg/L of organic phosphorus and 1 to 15mg/L of inorganic phosphorus. (21.)

The mean value of chromium found in industrial landfill leachate 0.004-0.008 mg/L. For comparison the concentration of chromium in diluted domestic wastewater is 0.015mg/L (Table 6.3).The mean value of suspended solid is not presented. The suspended solid average is about 200mg/L in domestic landfill leachate, although the higher levels may be reached. (24)

Table 6.3 Parameters in domestic wastewater. (23.)

Parameters	**Unit**	**Wastewater type**				**Leachate**
		Concentrated	**Moderate**	**Diluted**	**Very diluted**	**Mean**
Suspended solids	mg/L	450	300	190	120	224.1
Conductivity	mS/cm	0.12	0.1	0.08	0.07	3.539
pH		7-8	7-8	7-8	7-8	7.17
Chromium	mg/L	0.04	0.025	0.015	0.01	0
Iron	mg/L	1.5	1	0.6	0.4	1.46
Nitrate, HR	mg/L	0.0005	0.0005	0.0005	0.0005	1.1

The suspended solids in concentrated domestic wastewater are 450mg/L, and the mean value of landfill leachate in this study is 224.1mg/L. The content of suspended solids is lower in leachate than in domestic wastewater (Table 6.3).

The concentration of sulpate in domestic wastewater is in the range of 15-30mg/L. For phosphorus the range in domestic wastewater is 2-20mg/L also. It means the concentration of sulfate and phosphorus is generally lower in leachates than in domestic wastewater. (Table 6.3)

7. Conclusions

For the management of landfill leachate, the first step is according to the literature research is to study the circumstances in generation of landfill leachate, the composition of landfill leachate, the characteristic of leachate and the typical landfill design how to control and monitoring the leachate generation. The constructed wetlands are an efficient natural system for leachate treatment. It can save costs and be efficient method in pollutant removal. The biological, physical and chemical processes are always needed in leachate treatment technology.

Otherwise, through the laboratory work some of parameters were selected to describe the characteristics of leachate. The analysis is used as basic information in a project which is done in collaboration with TAMK University of Applied Sciences and Kunming Institute of Environmental Science. The concentration of heavy metals is high in leachate sample, and the conductivity in leachate is lower than in domestic wastewater. The leachate contains more contaminants than domestic wastewater and thus needs efficient treatment process before disposal.

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Appendix 1

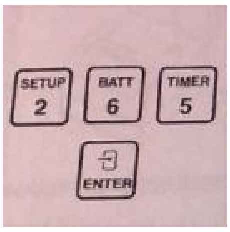
(1.) Instruction for HACH Spectrophotometer (iron)

For example, The HACH Spectrophotometer measure the range of iron (total) is from 0 to 3.00 mg/l. The operation instruction for measure the Ferro within the filtrated leachate sample is according to the following steps from (a.) to (k.) and the figure shows the detail of the process, others composition measurement is basically the same, only the program number, the size of sample cell (10ml or 25ml), waiting time and the type of Reagent powder pillow are different.

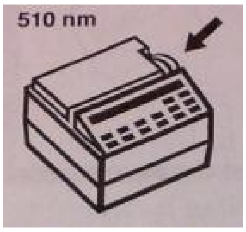
(a.) Enter the stored program number for iron (Fe) Ferro should press: *265* and enter again, the display will show: *Dial nm to 510*.

(b.) Rotate the wavelength dial until the small display shows: *510 nm*. When the correct wavelength is dialed in, the display will quickly show: *Zero Sample*, then: *mg/L Fe FV*.

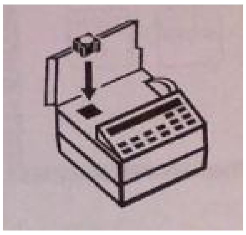
(c.) Insert the Cell Riser for 10-ml sample cells.



(a.)



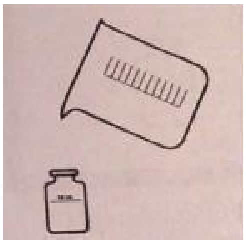
(b.)


(c.)

(d.) Fill a clean sample cell with 10ml of sample.

(e.) Add the contents of one Ferro Ver Iron Reagent Powder Pillow to the sample cell (the prepared sample). Swirl to mix.

(f.) Press: *SHIFT TIMER*. A three minute reaction period will begin.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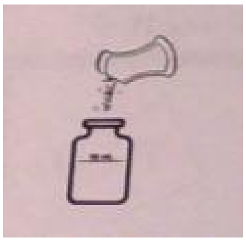
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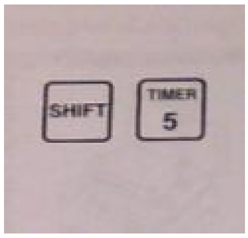
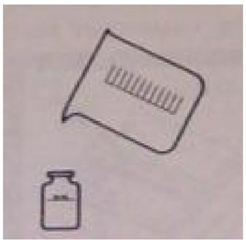
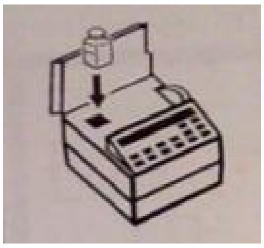
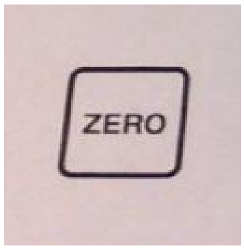


(f.)

(g.) When the timer beeps, the display will show: *mg/L Fe FV*. Fill another sample cell with 10ml of sample (the blank).

(h.) Place the blank into the cell holder. Close the light shield.

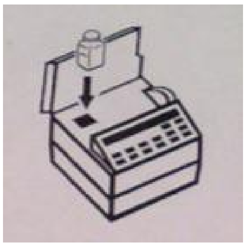
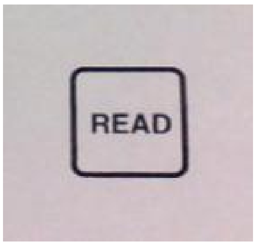
(i.) Press: *ZERO*. The display will show: *Zeroing…* then: *0.00 mg/L Fe FV*.


(g.)

(h.)


(i.)

(j.) Within thirty minutes after the timer beeps, place the prepared sample into the cell holder. Close the light shield.

(k.) Press: *READ*. The display will show: *Reading…* then the result in mg/l iron will be displayed.


(j.)


(k.)